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AUTHORITY

**RADC ltr 17 Sep 1971**

# CONTINUED STUDIES ON ADVANCED FERROMAGNETIC MATERIALS APPLIED TO DIGITAL PHASE SHIFTERS

## THIRD QUARTERLY REPORT

29 August 1966 through 28 November 1966

ARPA ORDER NO. 550
PROGRAM CODE NO. 6E30

SPERRY

TECHNICAL REPORT

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| CONTRACTOR: | SPERRY MICROWAVE ELECTRONICS COMPANY |
| DATE OF CONTRACT: | 28 February 1966 |
| AMOUNT OF CONTRACT: | $146,794.00 |
| CONTRACT NUMBER: | AF30(602)-4122 |
| CONTRACT EXPIRATION: | 28 February, 1967 |



**SPERRY MICROWAVE ELECTRONICS COMPANY**
DIVISION OF SPERRY RAND CORPORATION
CLEARWATER, FLORIDA



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# I. Introduction

## 1.1 Background

During the course of the previous program, entitled "Advanced Ferrimagnetic Materials Applied to Digital Phase Shifters", a considerable amount of information was accumulated on ferrite digital phase shifter materials and structures. The square loop and microwave properties of many ferrimagnetic garnets and ferrites were investigated. Structures employing these materials were also evaluated at both low and high power levels. The investigations were made principally in the 3 to 10 GHz frequency range.

The purpose of the present program is to derive a number of ferrimagnetic materials for use at high power levels below 3 GHz. Since it is unlikely that the low frequency structures will be basically different than those used at frequencies above 3 GHz, improvement in the phase shifter operating characteristics will probably depend primarily on improvements in the materials.

## 1.2 Program Objectives

The objectives of this program are directed toward the improvement and evaluation of ferrite and garnet materials for use in digital phase shifters. Effort will be applied in the following areas:

1.2.1 Improvement and evaluation of ferrite and garnet materials for use in digital phase shifters at L-, S-, C- and X-bands will be pursued with increased effort at the lower frequency bands. Emphasis will be placed on development of

peak power capability of the order of 100 kilowatts while generating insertion losses of 1 db or less and phase stability with temperature variation over the military range.

1.2.2 Microwave digital phase shift structures will be studied with special emphasis on materials derived in this program combined with the requirements for high switching speed, low switching power, low loss, low holding power, compact configuration, low unit cost, and high peak and average power handling capability.

1.3 Assignment of Responsibility for the Program

This program is assigned to the Engineering Department of the Sperry Microwave Electronics Company. Dr. R. E. Henning is the Chief Engineer. Overall responsibility for the program is in the Microwave Equipment Department with Mr. B. J. Duncan, Engineering Manager. Direct responsibility for the program is in the Research Section with Dr. G. R. Harrison, Section Head. Mr. D. R. Taft, Senior Staff Engineer, is the Project Engineer and is also responsible for the rf evaluation of the materials and the structures. The materials investigations in the program are being conducted by Mr. L. R. Hodges, Senior Staff Engineer, and Mr. W. R. Wilson, Engineer. Consulting services will be provided by Dr. G. P. Rodrigue and Dr. J. L. Allen of the Research Section.

## II. Narrative Summary of Work Performed from 29 August, 1966 through 28 November, 1966

During this quarterly period, testing was continued according to the tasks outlined in the First Quarterly Report.

The fabrication of the materials needed for the microwave and materials investigation has been completed except for a magnesium-manganese ferrite sample to be used in a below resonance (frequency) fashion in L-band. This is a recently added task. Some of the measurements of materials properties (such as $4\pi M_s$, $\Delta H$, etc.) are still incomplete, but these data should be accumulated by the end of this quarter.

Grain size studies have not as yet yielded any new information. However, inhomogeneities, principally those associated with porosity are still felt to be one of the main factors affecting the ferrite square loop properties as indicated in the last Semiannual Report.

An isostatic press for forming of the ferrite bars for final firing was recently received. The advantage of this type press over the conventional type is that the pressure is uniformly applied over the bar surface. In comparison to the conventional pressing technique, this should yield ferrite bars with higher and more uniform density and thus less inhomogeneities.

As soon as this press is operational, new ferrite samples will be fabricated with it from the same powder batches as previously used. This will be done on several of the more important square loop materials such as YIG, 15% and 30% aluminum doped YIG and possibly others. Square loop and microstructure properties of these materials will be compared with those of samples prepared in the conventional press.

In X- and C-bands the low and high power microwave testing is nearly completed. A great deal of RF performance information was obtained about these materials such as magnetic loss, differential phase shift, total loss per 360° of phase shift and critical fields ($h_{crit}$). The results of all these tests have agreed very well with the theoretical work making it possible to predict or extrapolate to other frequency ranges, higher power levels, etc. with reasonable confidence.

The six garnets and one ferrite material listed in the First Quarterly Report for L-band testing have now been received. Several of the garnets have been tested in rectangular waveguide for above resonance performance (frequency wise) and two materials have been tested for below resonance performance at low RF power levels. In addition a magnesium-manganese ferrite is being fabricated for below resonance operation. It appears that in above resonance operation in this band, materials having low enough values of magnetization to permit high power operation will either be relatively inactive (< 10 degrees/inch) requiring great lengths of material, or will be lossy because of rare earth doping if this is the approach used to obtain high power capability.

It is hoped that below resonance operation will be the answer for low frequency operation at high peak power levels. A medium-high power source (approximately 300 kw maximum peak power) has been made available to the program. High power testing will be conducted in the 1200 to 1450 mc range for both above and below resonance operation.

If time permits, some materials will be tested for high speed switching capability as determined by the switching coefficient (Sw). This information is useful in calculating the switching time of a material when driven by a known magnetic field. This work would, of course, be limited to those materials having desirable microwave and other square loop properties.

## III. Fiscal Data

The following tabulates the fiscal data on the program:

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|---|---|
| Engineering man hours expended during this quarter | 1050 |
| Engineering man hours expended to date | 3370 |
| Expenditures during this quarter | $31,940.00 |
| Projected expenditures for this quarter | $36,700.00 |
| Total expenditures to date | $115,736.00 |
| Projected total expenditures to date | $108,000.00 |